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# Supporting Students' Understanding of Percentage

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***Abstract***

Many researches revealed that pupils often find difficulties to understand percentage although they are able to recite percent as per hundred and carry out the computations correctly. This might happen due to the way in which the learning percentage has been taught that tends to focus on procedures and recall instead of getting a real understanding of percentage. In Realistic Mathematics Education approach, in which the basic concept is rooted from Freudenthals' idea, mathematics is the activity of organizing matter from reality. Therefore, mathematics should be experientially real for the students. Consequently, in this research the instructional activities were designed through exploring some contextual situations in which percentages play role.

Therefore, this research aimed to develop a local instructional theory to support students to extend their understanding of percentage. This research used design research method as an appropriate means to achieve the research aim. The research involved students and mathematics teachers of grade 5 in SD Laboratorium UNESA and SD BOPKRI III Demangan Baru Yogyakarta.

**Keywords**: design research, percentage, understanding, contextual situations

**Abstrak**

Banyak penelitian mengungkapkan bahwa siswa sering menemukan kesulitan untuk memahami persentase meskipun mereka mampu melafalkan persen per seratus dan melakukan perhitungan dengan benar. Hal ini dapat terjadi karena cara di mana persentase belajar telah diajarkan yang cenderung fokus pada prosedur dan ingat bukan mendapatkan pemahaman yang nyata dari persentase. Dalam pendekatan pembelajaran matematika realistik, dimana konsep dasar berakar dari ide Freudenthals, bahwa matematika adalah kegiatan pengorganisasian materi dari kenyataan. Oleh karena itu, matematika harus berdasarkan pengalaman nyata bagi siswa. Akibatnya, dalam penelitian ini kegiatan instruksional yang dirancang melalui mengeksplorasi beberapa situasi kontekstual dimana persentase berperan.

Oleh karena itu, penelitian ini bertujuan untuk mengembangkan teori instruksional lokal untuk mendukung siswa untuk memperluas pemahaman mereka tentang persentase. Penelitian ini menggunakan metode desain penelitian sebagai sarana yang tepat untuk mencapai tujuan penelitian. Penelitian ini melibatkan siswa dan guru matematika kelas 5 di SD Laboratorium UNESA dan SD Bopkri III Demangan Baru Yogyakarta.

**Kata kunci**: *design research*, persentase, pemahaman, pengetahuan awal, situasi kontekstual

Percentage is one of the most widely used mathematical topics in daily life and holds substantial place in the school curriculum for almost any science and social studies (Arthur J. Baroody et al, 1998; James E. Schwartz et al, 1994; Parker and Leinhardt, 1995). Understanding of percentage is necessary to ensure proper interpretation of social studies, science materials, and many situations in daily life (James E. Schwartz et al, 1994). Percentages are not only another way of writing down simple fractions, but also derive their right to exist from the limitations of regular fractions; fractions are difficult to compare with each other, and the scale that they provide is rather unrefined (Galen et al, 2008).

Considering the importance of percentage in daily life, percentage has been taught since elementary school. However, many percentage problems indicate that education is primarily focused on procedures and recall instead of getting a real understanding of percentage (Van den Hauvel-Panhuizen, 1994). The finding in the study of Koay (1998) shows that ability to recite percent as per hundred and carry out the computations correctly does not lead to the ability to interpret and apply the concept in context. It is easier for students to perform computation problems than to explain the meaning of percent and also knowledge of percent was often rigid and rule-bound (Koay, 1998).

In Realistic Mathematics Education where teaching is built on the informal knowledge of the students, it is important to give students the opportunity to explore some daily life situations in which percentages play a role (Van den Hauvel-Panhuizen, 2003). This idea is relevant with Freudenthal’s idea that views mathematics as a human activity instead of seeing mathematics as a subject to be transmitted (Freudenthal, 1991). Therefore, mathematics should be experientially real for students. There are some daily life situation problems that can be used as the contextual problems for students to learn percentage. Some of those are loading process, discount, and free extra context.

Mathematics in Indonesian curriculum tended to be taught in a very formal way; teachers explain the mathematics operation and procedures, give some examples, and ask pupils to do the other similar problems (Armanto, 2002). Formal way of teaching on percentage tends to restrict pupils' creativity and flexibility in their strategies to solve the percent problem. Although the students have learned percentage in the school, it does not mean that they understand about percentage. Hence, the question of this research is "*How to support students to extend their understanding of percentage?*".

## ***Theoretical Framework***

### **Percentage**

According to Parker and Leinhardt (1995), percentage can describe part whole relationship and can describe a ratio based upon the meaning of percentage. Percentage as part whole relationship describes relative value of the part compared to the whole. Percentages are relationships based on a one-hundred-part whole and it gives relative measure, not an absolute measure (Fosnot & Dolk, 2002). Students do not have to explain this in this manner, but they have to show an awareness of the fact that percentages are always related to something and that they therefore cannot be compared without taking into account to what they refer (Van den Heuvel-Panhuizen, 1994). In this research, the researcher only focused on the meaning of percentage as part whole relationship. Researcher only focused on this meaning because it is the most salient of comparative situations, imaginable for young students in grade 5, and can support students understanding of percentage as relationship based on one-hundred-part whole.

Learning process of percentage should include goals concerning the understanding of percentage and also computational goals. With respect to computational goals, a variety of types of computations with percentage are explored, such as compute the part of a whole while the percentage is given. However, it is more important that students are able to use percentage in a situation in which they are needed, when different parts of different wholes have to be compared (Van den Heuvel-Panhuizen, 1994).

**The Didactical Use of Bar Model**

Although the meanings of percentage are diverse, the essence of percentage is proportionality; percentage is used to describe proportional relationship (Parker and Leinhardt, 1995). This aspect of proportional relationship involving an equivalent relationship between two ratios suggests that there is needed to offer an appropriate model to support student to reason proportionally. The model offered in this research is bar model.

The use of model bar in learning percentage is beneficial for students. The first benefit is that bar model has area that makes it easier to talk in terms of “the whole” (Galen et al, 2008). As the second benefit, the bar model gives a good hold for estimating an approximate percentage, especially in cases where the problems concern numbers that cannot be simply converted to an simple fraction or percentage. The third benefit is that the bar model provides the students with more opportunity to progress. This also means that the bar model can function on different levels of understanding (Van den Heuvel-Panhuizen, 2003).

**Realistic Mathematics Education**

Realistic Mathematics Education is rooted in Freudenthal’s interpretation of mathematics as a human activity (Gravemeijer, 1994). Based on Freudenthal’s idea, mathematics must be connected to reality, stay close to students and should be relevant to society. The characteristics of RME were used as a guideline in designing the instructional activity. Treffers (1987) defined five characteristics of RME as follows.

1. Phenomenological exploration

   In the first of instructional activity, the mathematical activities take place within a concrete context. This mathematical activity should be experientially real for students.

2. Using models and symbols for progressive mathematization

   In learning mathematics, varieties of vertical instruments such as models and symbols are offered, explored, and develop to bridge the level difference from a concrete level to a more formal level.

3. Using students' own construction and productions
   Giving opportunities for students to explore and contribute various strategies can support students' individual productions. Students' own productions can indicate where they are and how they progress in learning process.
4. Interactivity
   Interaction among students and between students and teacher can support the development of students' learning process.
5. Intertwinement
   In designing an instructional activity, it is important to do integration of the various domains.

**Hypothetical Learning Trajectory of the Preliminary Researches**

Since this research was conducted in three cycles and in two different schools, then the Hypothetical Learning Trajectory (HLT) and analysis on the first and second cycle became the theory of this research. The HLT 1 was implemented in the first cycle of experiment in SD Laboratorium Unesa. Based on the analysis of the first cycle of experiment, the researcher improved and adjusted some activities in HLT 1. The HLT 2 as the refinement of HLT 1 was also implemented in SD Laboratorium Unesa but in other group.

***Research Method***

**Design Research Methodology**

The aim of this research is to develop a local instructional theory to support students to extend their understanding of percentage. For this need, this research used a type of research method namely design research for achieving the research aim. Design research is a type of research methods aimed to develop theories about both the process of learning and the means that are designed to support that learning (Gravemeijer & Cobb, 2006).

Gravemeijer & Cobb (2006) define what design research is by discussing the three phases of conducting a design research, namely:

1. Preparation and design phase
2. Design experiment
3. Retrospective analysis

**Hypothetical Learning Trajectory**

Bakker (2004) said that a design and research instrument that proved usefull during all phases of design research is the so-called 'hypothetical learning trajectory'. A hypothetical learning trajectory (HLT) is the link between an instruction theory and a concrete teaching experiment. Simon (1995, in Simon and Tzur, 2004) described that an HLT consists of the goal for the students' learning, the mathematical task that will be used to promote student learning, and hypotheses about the process of the students' learning. During the preliminary and teaching experiment, HLT was used as a guideline for conducting teaching practice. HLT was also used in the retrospective analysis as guideline and point of reference in answering the research question.

**Research Subjects**

The research was done in the fifth grade of SD Laboratorium UNESA and SD BOPKRI III Demangan Baru Yogyakarta, Indonesia. Around twenty five students in each school were involved in the experiment. The students are about 10 to 11 years old and they have learned about percentage in the school.

**Data Collection**

The data collection of this research was described as follows:

a. Video

In this research the video data provides the primary data. The video recorded the activities and discussion in the whole class and in some groups of students, and also recorded the interviews with teacher and some students.

b. Written data

In this research, the written data includes student's work, observation sheet, assessments result, and some notes gathered during the experiment.

**Reliability and Validity**

Reliability has to do with the quality of measurement. In this research, ensuring the reliability was improved by doing two ways, namely data triangulation and cross interpretation. Data triangulation relies upon gathering data from multiple sources during the experiment. The data in this research was gathered by videotaping the learning experiment, collecting students' works, and collecting notes from observation and interview. Cross interpretation was conducted by discussing data gathered during the teaching experiment with the supervisors and the colleagues. The cross interpretation was conducted in attempt to minimize the subjectivity of the researcher's point of view.

Internal validity refers to the quality of the data collection and the soundness of the reasoning that has led to the conclusion. In this research, the internal validity was kept by two ways, namely testing the conjectures during the retrospective analysis and trackability of the conclusions. The teaching experiment was documented by videotaping the learning experiment, collecting written data. By using this data, the researcher was able to describe detailed information of the reasoning that leads to the conclusion.

***Hypothetical Learning Trajectory***

The set of instructional activities of this research is described in the hypothetical learning trajectory. The following are the main activities of the research.

a. Investigating loading process

Description:

Students are asked to estimate the percentage of the loading process and also to shade the part of loading bar that is fully loaded.

Goal:

- Students are able to construct the *sense* of percentage.

  Conjectures:
- Students just estimate how much the part that is fully loaded
- Students might measure the length of the bar by using ruler, and divide the bar into five, ten or twenty parts.

b. Estimating percentage of area problems

Description:

Students are asked to estimate the percentage of area problem by or without grid paper.

Goals:

- Students are able to construct the meaning of percent as "so many out of 100".
- Students are able to work with benchmark percentages.

Conjectures:

- Students might use grid paper to estimate the percentage.
- Students might use their own drawing and divide the drawing into some equal parts.
- Students might use algorithm to find the percentage.

c. Investigating two different percentages of discount

Description:

Students are given a poster about advertisement of two shoe shops offering two different discounts. Then, students are asked to determine which shop they will prefer.

Goal:

- Students are able to construct sense of percentage as relative value

Conjectures:

- Students will prefer Sriwijaya shop because the discount is bigger than those in Istana shop so that the price will be cheaper.
- Some students might realize that the original prices in both shops might be different.
- Students might prefer Istana shop because of other considerations such as the quality or the distance of the shop.

d. Determining the sweeter drink

Description:

Students are given two glass of syrup having different volumes of extract orange and also different total volumes of drink. Then, the students are asked to determine which drink is the sweeter drink.

Goal:

- Students are able to use percentages in a situation in which percentages are needed, that is in a situation in which different parts of different wholes have to be compared.

Conjectures:

- Students maybe will order those drinks based on the volume of the syrup without considering the volume of the drink.

- Students might use fractions to determine the concentration of extract orange and then compare those fractions by using decimal.
- Students might estimate the concentration of syrup in each glass by using percentage.

e. Investigating extra free problem

Description:

Students are asked to draw a chocolate having 50% extra free.

Goal:

- Students are able to extend their knowledge to percentage greater than 100.

***Retrospective Analysis***

**The first cycle in a small group of students in SD Laboratorium UNESA**

The first try out in some students in grade 5 of SD Laboratorium Unesa showed that the students already knew that percent means per hundredth and they were able to do computation using percentage, especially by using algorithm. It was because they had learned percentage before. However, it does not mean that all students completely understand the concept of percentage. Other findings from the first try out were that some students were not able to use their previous experience in solving new percentage problem. Moreover, the students did not seem to pay attention to the preciseness of the measure or comparison.

**The second cycle in SD Laboratorium UNESA**

The research subject in this second cycle already had knowledge about percentage; most of them knew that percentage means per hundredth and they are able to do the computation. However, the result of post test showed that many students struggled to figure out or make a drawing of the situation involving percentage (e.g. in shading 90% of the field), and some of the students often made mistake because they forgot the 'rule' in solving percentage problem. Students in grade 5 showed that they need precision in measuring the length of their drawing or model to help them to solve the percentage problem. In the second cycle, there are some activities that need to be adjusted and revised due to misunderstanding or difficulties faced by the students in solving the problem.

**The third cycle in SD BOPKRI III Demangan Baru Yogyakarta**

a. Investigating loading process

From investigating loading process and the class discussion, the students can imagine how the percentage runs along the scale as well as the shaded part representing the fully loaded area. Overall, in this activity most of the students had already perceived the sense of *fullness* of percentage.

b. Estimating percentage of area problems

The students could explore the meaning of percent as so many out of a hundred through exploring the area problem with the support of grid paper. However, the researcher made a highlight of this accomplishment. As the reflection was that this instruction was not really challenge the students to really think about the meaning of percent as so many out of a hundred. The researcher conjectured that it was caused by two things. The first was that the students were too much assisted by patterns and structures that were provided in the problems. The second was that the numbers involved in the problems were beautiful numbers (multiple of a hundred) so that it was easy to talk about percent.

c. Investigating two different percentages of discount

As the conclusion, it is showed that almost a half of the students seemed to start aware that in comparing discount they cannot only compare the percentage of discount absolutely but they have to know the reference of the percentage. This finding indicated that those students started to be aware that percentages of discount give relative value and not absolute value so that one could not compare it directly without taking into account to what they refer.

d. Determining the sweeter drink

By the support given by the teacher, the students finally realized that they could not compare directly the volumes of extract orange in determining which drink is the sweeter drink. They finally realized that they should compare the volume of extract orange with the total volume of drink. However, although the students realized the idea of comparing relatively, they still struggled to use their previous knowledge, especially about percentages, in solving this problem.

There was an interesting finding in this activity. Gandhang is one of the students who compared absolutely the volume of extract orange to determine which drink is the sweeter drink.

e. Investigating extra free problem

Most of the students started to realize that percentages greater than a hundred indicate that something is increase. However, only few of the students could do the flexible calculation by using splitting strategy.

### *Conclusion*

Designing a hypothetical learning trajectory is not an easy and a simple thing to do. A deep understanding about mathematical ideas of a topic and the pedagogical competences of a teacher are needed in designing a hypothetical trajectory. The learning process that focuses on students' understanding needs a good cooperation between students and a teacher. In such of learning, a teacher plays role in building a conducive classroom culture and facilitating students to build their knowledge. A teacher also should be able to explore learning sources that is potential in supporting students to build their knowledge. The potential learning sources that can be explored by the teacher are situations or problems that are experientially real for students.

In this research, in supporting students to extend their understanding of percentage, the students were confronted with some daily life situations in which percentages play role such as loading process, discount, area, and free extra context. Since the students have learned about percentage in the school, the students knew the procedural algorithm to solve percentage problem, especially when they have to compute part of a whole while the percentage is given. Therefore, the researcher should adjust some activities so that they could not directly use their procedural algorithm.

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